

NOAA Technical Memorandum ERL PMEL-54

METLIB-II - A PROGRAM LIBRARY FOR CALCULATING AND PLOTTING  
ATMOSPHERIC AND OCEANIC FIELDS

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April 1984



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DEPARTMENT OF COMMERCE**

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ABSTRACT. METLIB-II is a FORTRAN program library for deriving time series of geostrophic, gradient, or surface winds from sea level pressure (SLP) and ancillary fields gridded on a polar stereographic projection. Such fields are generated at the National Meteorological Center (NMC) and at Fleet Numerical Oceanography Center (FNOC); they can also be generated by digitizing SLP charts analyzed manually. The library also contains programs for contouring scalars, such as SLP, air temperature, or wind speed, and for plotting wind vectors on a map background. Plotting is based upon the National Center for Atmospheric Research (NCAR) graphics routines. A major advantage of the library is that spherical geometric calculations involving polar stereographic grids are internal to the programs. The relationship between geostrophic or gradient wind and surface wind can be assigned from speed reduction and turning angle constants or by a baroclinic, stability-dependent, single point boundary layer model.

METLIB-II differs from METLIB in that the software was revised to increase efficiency of calculation. Internally, names of programs, functions, and subroutines were changed to give a clear indication of their purpose; documentation was revised and increased to give the user an exact explanation of each step in the software. The user is able to specify more input conditions and request more output variables, such as heat flux, vapor flux, momentum flux, etc. Some boundary layer solution subroutines were extensively modified.

\*Contribution No. 612 from NOAA/ERL Pacific Marine Environmental Laboratory.

## 1. INTRODUCTION

This document provides an introduction to the program library, the data structure used by the library, and documentation of the geophysical algorithms used to derive various parameters and perform geometric calculations. The library is divided into nine program divisions: UNPACK or DECKS; WINDS; PNTWIND or TRKWIND; three utility programs; PLOTGRD; and two subroutine libraries, WSUBLIB and PSUBLIB.

UNPACK extracts data from a larger data set, normally on tapes such as those supplied by the National Center for Atmospheric Research (NCAR) or the National Meteorological Center (NMC), and creates a master file in a standard format for all subsequent programs. DECKS performs the same function as UNPACK for card or terminal input of fields that have been digitized from manual analyses. Program WINDS inputs a series of sea-level pressure (SLP) fields in standard format and, depending upon the option, can also input air temperature, air-surface temperature difference, dew point depression, and surface roughness fields. It outputs u and v wind components at each grid point. Output winds can be geostrophic, gradient, empirically reduced and turned geostrophic or gradient, or calculated from one of three planetary boundary layer (PBL) models. Two of the three PBL models have the option of outputting stress or heat flux in addition to the surface wind. PNTWIND can take u and v fields generated by WINDS, interpolate them to any specified latitude and longitude, and convert the grid components to speed and direction relative to north; TRKWIND performs a similar function on a time series of latitudes and longitudes. The plotting portions of METLIB-II are based upon NCAR's Scientific Computing Division Graphics package (McArthur, 1981). PLOTGRD can input and contour up to two scalar fields and can plot their

difference. It can draw arrow plots of a vector field or the difference of two vector fields, and can plot a vector field with contours of a scalar, including contours of the magnitude (isotachs) of the vector field itself or the difference in magnitude of two vector fields. All routines are intended to be machine-independent FORTRAN 66 programs.

For use at the Pacific Marine Environmental Laboratory (PMEL) or other locations with access to the Environmental Research Laboratories' (ERL) CDC Cyber 750 computer in Boulder, Colorado, SUBMIT files are shown for each of the main programs for METLIB-II. These SUBMIT files all have filenames beginning with the letter J and are specific to the NOS 2.0 operating system in use at the time of publication.

METLIB-II is a direct outgrowth of METLIB - A PROGRAM LIBRARY FOR CALCULATING AND PLOTTING MARINE BOUNDARY LAYER WIND FIELDS by Overland, et al. (1980). METLIB-II offers a more liberal choice of input and output fields, computes more accurately and efficiently, and provides three levels of output documentation. Internally, subroutine and program names have been changed to better reflect their purpose, and documentation has been added at appropriate steps. The surface wind model 6 has been revised extensively. Complete listings of programs and subroutines are available from the authors.

## 2. COMPUTING WITH METLIB-II

METLIB-II is a library of FORTRAN programs that are used for batch processing; this means that jobs are submitted to the computer for processing independent of any other computer execution a user may be undertaking, such as a terminal session. We proceed in this manner because METLIB programs

often require the mounting of tapes or disk packs, and require lengthy execution times because of the vast amount of data that is processed. Batch processing allows the user to continue interacting with other computer work at the terminal without waiting for the METLIB job to terminate.

Most METLIB jobs have four components:

1. input data files,
2. Fortran program and subroutine library,
3. output data files, and
4. job control language (SUBMIT files) to instruct the computer on how to assign, link and execute the above three items.

Input data files may be in the form of raw data tapes or card decks, but generally they will be gridded data created with a format compatible with the programs presently residing in METLIB. Output data, too, are generally METLIB format files. The Fortran programs and their required input and output data assignments are discussed in section 5 of this document. We have tried to use standard Fortran 66 statements throughout the library, however, the UNPACK routine, for reading raw data tapes, uses system-defined, word-size-dependent utilities that will depend on the conditions set by the computer which created the tapes. Job control statements in the SUBMIT files are dictated by the operating system employed by each particular computer. Examples of job control language for the Network Operating System (NOS) in place on the NOAA Cyber 750 computer in Boulder, Colorado, are presented for each main program. Figure 1 gives a brief explanation of each of the job control statements in the SUBMIT file JWINDS. All the ATTACH statements assign a logical unit number (for example, TAPE10) to each input and output data file. The many available program options are controlled by the data card variables set by the user. Many of the data cards are in free



/JOB	tells the computer to expect a sequence of job control statements
JWINDS.	name of the SUBMIT file
*	a star in column 1 followed by a space indicates a comment card
/READ,USERID	reads the user's name, charge, project number, and routing information (for printed output) from a file created by the user called USERID (resides in the user's permanent file space)
/NOSEQ	allows data entry to begin in column 1
GET,WINDS.	finds the specified main program (ex. WINDS) in the user's permanent file space and makes it accessible to the job sequence
FTN,I=WINDS,R=0,L=0,PMD.	compiles the specified Fortran program; R,L and PMD are output specifications
RETURN,WINDS.	releases the uncompiled copy of WINDS
GET,WSUBLIB/UN=METLIB.	finds the subroutine library WSUBLIB in account METLIB
ATTACH,TAPE10=SLP/NA.	finds the input data file (SLP), assigns it to logical unit 10, and makes it accessible to the program
IFE,FILE(TAPE10,BOI),NOFILE.	if TAPE10 is not attached or rewind then skip to the ELSE,NOFILE. statement
	same (ATTACH followed by an IFE statement) for all input data files shown in figure 6.

Figure 1. An annotated version of the SUBMIT file JWINDS illustrates the meaning of the NOS 2.0 job control language used in METLIB-II. The words and numbers in italics are set by the user and are explained in sections 4 and 5.

```

DEFINE,TAPE21=SFCU/NA.
ATTACH,TAPE21=SFCU/M=W,NA.
LDSET,LIB=WSUBLIB.
LGO.
ELSE,NOFILE.
COMMENT. INPUT TAPE NOT ATTACHED
ENDIF,NOFILE.
/EOR
82 10 18 00 01 04 00 0.90 30.0
0 0 0 1 0 0 1 0 0 0
      EMPIRICAL CONSTANTS, 18 OCT 82 00Z
/EOR
/EOF

```

creates a file called SFCU and assigns it to logical unit 21, if SFCU already exists in the user's file catalogue this statement will fail

if SFCU already exists in the user's file catalogue, ATTACH makes SFCU accessible to the job for writing the output (surface wind u component) of the program

same (DEFINE followed by an ATTACH statement) for all output data files shown in figure 6.

loads the subroutine library into LIB where the program can access the subroutines with a CALL statement

executes (or runs) the compiled program

if any of the IFE statements are true, the computer skips the intermediate statements and prints the COMMENT

ends the portion of the SUBMIT routine to which IFE skips

end of record signals the end of the job control language

end of record signals the end of the data cards

end of file signals the end of this job

Figure 1. (continued)

field format meaning that the numbers must only be in the correct order and separated by commas or spaces.

METLIB is generally used in the following sequence: first, raw pressure (and sometimes, temperature, humidity, etc.) fields are transformed into METLIB files using DECKS (card decks) or UNPACK (tape); next, these METLIB files are submitted to WINDS to generate u and v wind components; maps of the wind, temperature, and pressure fields are then created by PLOTGRD; and finally, time series of winds are produced by PNTWIND or TRKWIND.

All the METLIB main programs, SUBMIT files, and subroutine libraries reside in a separate account on the ERL CDC computer in Boulder, CO. In order to keep the master account files unchanged, we ask that users with access to the ERL CDC make copies of the main programs and SUBMIT files they need. The appropriate changes (dimensions, file names, titles) can then be made and the programs can be submitted from the users' accounts.

### 3. DATA SOURCES

NMC currently produces SLP and surface air temperature (SAT) analyses at 0000 and 1200 GMT on one of two polar stereographic meshes: the PE 65 x 65 point grid, with a spacing of 381 km at 60°N, covering the northern hemisphere; and the LFM 53 x 57 point grid, a fine-mesh grid with a spacing of 190.5 km at 60°N, covering North America and the adjacent waters (Figures 2 and 3). PE and LFM are historical names standing for "Primitive Equation" and "Limited Area Fine-Mesh Model". The PE data are archived at NCAR (Jenne, 1975) and at the National Climatic Center (NCC). At present the LFM data are not routinely archived for general distribution. Pressure fields are also produced by the

Fleet Numerical Oceanography Center (FNOG) at 0000, 0600, 1200, and 1800 GMT on a 63 x 63 point grid with the same scale and orientation as the PE grid. All grids are uniformly spaced upon a polar stereographic map projection, which preserves angles (Figures 2 and 3).

Internal north-pole coordinates are (33,33) for the PE grid and (27,49) for the LFM. The FNOG pressure fields have pole coordinates of (32,32). For PE data prior to 1976 the NMC "octagon" was used. The number of grid points was 47 x 51, the pole location was (24,26), and the data were stored in a one-dimensional array. This is the format used by NCAR to store much of their NMC PE data.

Over the ocean, SLP and SAT values for operational forecast models are obtained from ocean-station vessel, buoy and ship observations analysed by a variety of objective analysis techniques (Cressman, 1959; Flattery, 1970; Holl and Mendenhall, 1971). For many research purposes it is necessary to reanalyze the SLP charts making use of reports that were not included in the NMC analysis. To this end, the reanalysis is done on a standard polar stereographic projection and digitized at a uniform spacing compatible with either the PE or LFM grids. The digitizing process is explained in the Appendix.

#### 4. DATA MANAGEMENT

All master data files created by UNPACK or DECKS are in a standard format for subsequent processing. Master data sets are arranged chronologically and separated by type (e.g., SLP or wind speed) and geographical region (e.g., the Gulf of Alaska). Thus, one file might have a

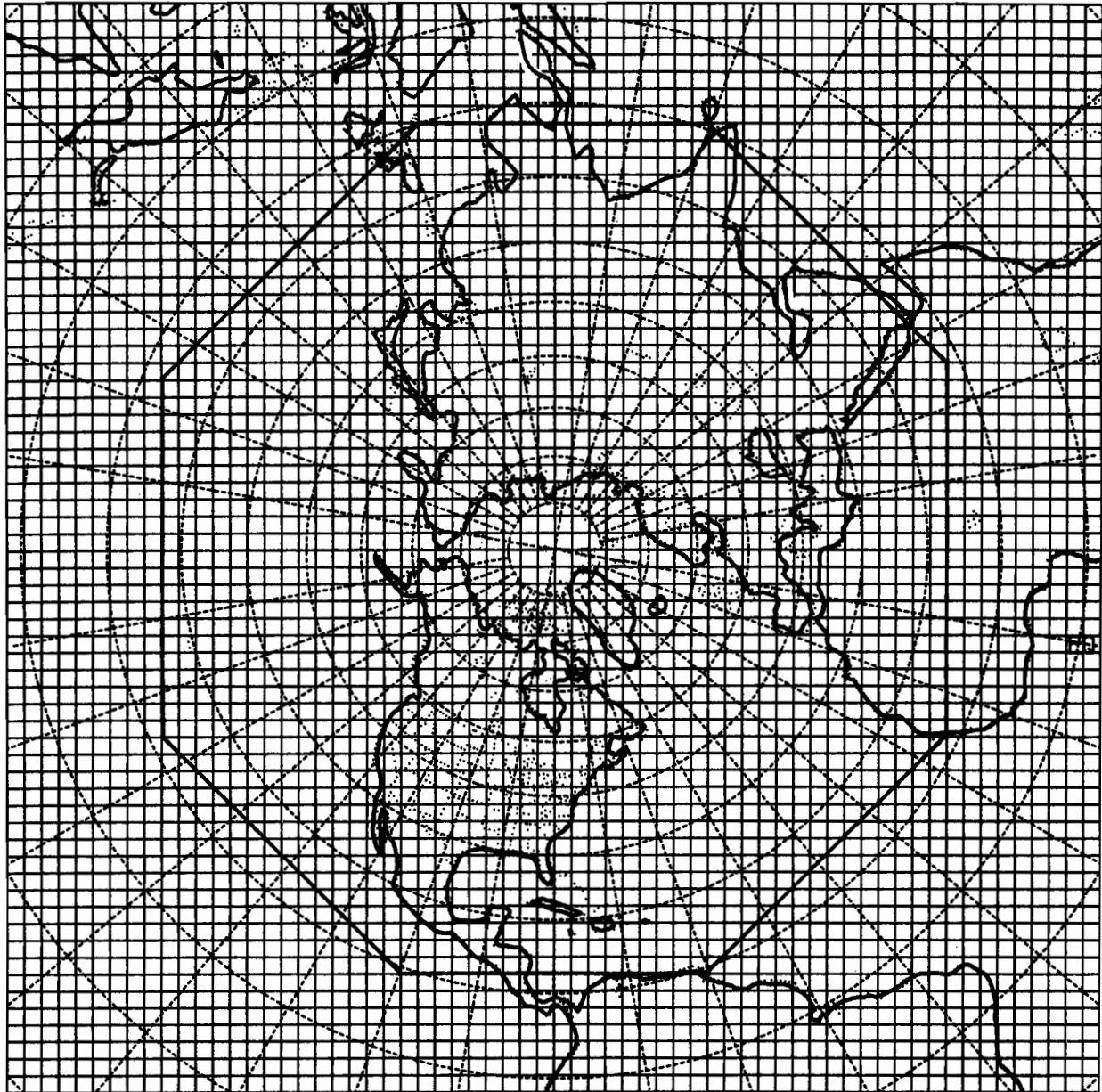


Figure 2. Some PE data are stored in a  $65 \times 65$  point grid. FNOC uses a  $63 \times 63$  grid with the same mesh point locations and center point. Prior to 1976, PE data were archived in the  $47 \times 51$  point NMC "octagon". These grids have internal north-pole coordinates (33,33), (32,32), and (24,26), respectively, and are IGRID options 1, 4, and 3 in programs UNPACK and DECKS.

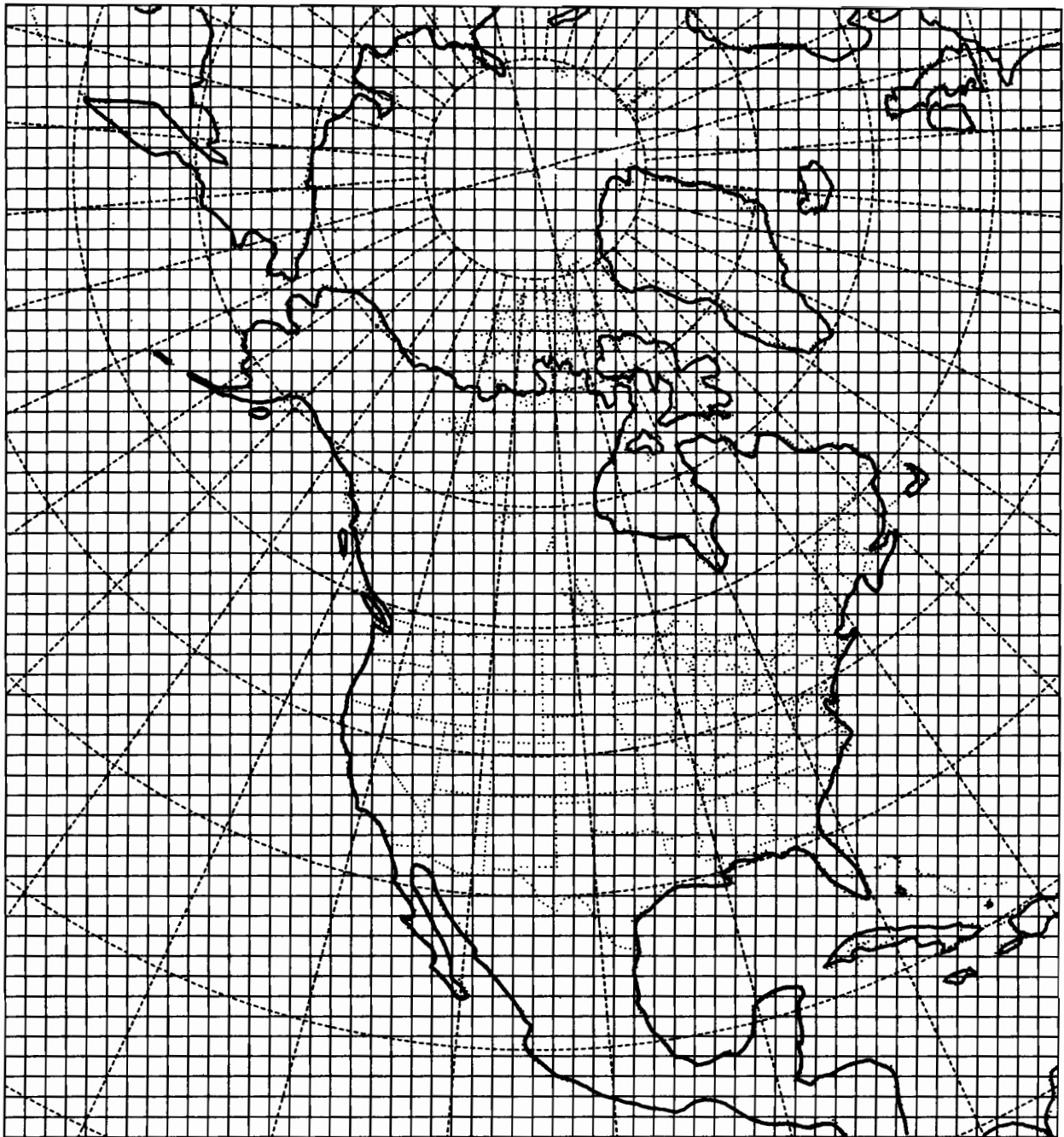


Figure 3. LFM data are stored in the NMC  $53 \times 57$  point grid with north-pole coordinates (27,49). This grid is IGRID option 2 in programs UNPACK and DECKS.

1-year time series of daily observed SLP's in a 10 x 10 grid for the Gulf of Mexico; another file might consist of model-generated, u-component winds for the same period, etc.

All records are generated by FORTRAN unformatted write statements and are stored in an unpacked form. Every METLIB data file is identified by a header record. This header is the first card in the data file and consists of six words that identify the particular grid on which the data are stored:

<u>Word</u>	<u>Quantity</u>	
1	IGRID	identifies the grid used (Fig. 1 and 2): = 1 designates PE, 2 designates LFM, 3 designates NMC octagonal (PE), 4 designates FNOG (PE);
2,3	XIS,XJS	the (I,J) coordinates (relative to the above grid) of the lower left corner of the data subregion;
4,5	IMC,JMC	the (I,J) dimensions of the data subregion relative to the above coarse (uninterpolated) grid.
6	IFACT	specifies the degree to which the input data have been interpolated relative to the coarse mesh: = 1 implies no interpolation, i.e., same as PE or LFM, 2 implies interpolation to 1/2 mesh, 4 implies interpolation to 1/4 mesh.

For example, if SLP were hand digitized on a grid twice as fine as the PE, IMC and JMC would equal the size of the equivalent coarse PE array, but IFACT would equal 2.

The header is followed by as many data records as necessary. Each record consists of a card containing seven identification words followed by the data. The identification words specify the date and data characteristics as follows:

<u>Word</u>		<u>Quantity</u>
1	IYEAR	"68" means 1968,
2	MONTH	"11" means November,
3	IDAY	"03" means the third day of the month,
4	IHOURL	"12" means 12 GMT,
5	ITYPE	data type coded as in NMC office note 84 (1973): = 8 implies pressure in mb, 16 implies air temperature in °C or °K, 17 implies dew point temperature (same units as air temperature), 18 implies dew point depression in °C or °K, 30 implies air-surface temperature difference in °C or °K, 88 implies relative humidity as a fraction of 1 (0-1), 384 implies surface temperature (in same units as air temperature);
6	IOBS	gives the type of forecast: = 0 designates observed data, 12 designates 12-hr forecast data, 24 designates 24-hr forecast data, etc., 910 designates climate type 1.0, 920 designates climate type 2.0, etc.;



7            IFLAG       flags missing data:  
                 = 0 means data are complete,  
                 1 means data are missing.

Following these identification words, the data array is written in words 8, 9, 10, etc. Missing data are given the value 9999. Two-dimensional arrays, A(I,J), are structured so that I and J increase in the same direction as I and J of the PE or LFM grids, with A(1,1) at the lower left corner of the subregion and the arrays reading ((A(I,J), I=1, IMC), J=1, JMC).

## 5. MAIN PROGRAMS

### 5.1 UNPACK (Used to Extract Subsets from Large Temporal or Geographic Data Sets such as NCAR)

UNPACK performs four tasks. It unpacks the data, if necessary; extracts the appropriate time series, subregion, data type, and forecast type as specified; interpolates the data to a finer (1/OFACT) mesh by biquadratic interpolation; and organizes the data set into the standard format for use by subsequent METLIB analysis routines. Since the raw data tapes come in different formats, UNPACK contains separate subroutines for each grid used (at publication time, subroutines exist only for the NMC octagonal and FNOC grids). The user specifies the start and stop time of the file to be generated, the grid to which the source data correspond, the lower-left-corner coordinates and dimensions of the region to be analyzed, the data type, the forecast types, the desired degree of interpolation, and the number of hours between map times on a single input data card with format (17I3) as follows:

IYSTRT. . . . the year of the first desired datum (e.g. 71 for 1971),  
 IMSTRT. . . . the month (e.g. 03 for March),  
 IDSTRT. . . . the day,  
 IHSTRT. . . . the hour,  
 IYSTOP. . . . the year of the last desired datum,  
 IMSTOP. . . . the month,  
 IDSTOP. . . . the day,  
 IHSTOP. . . . the hour,  
 IGRID . . . . the grid used:  
           = 1 for PE (65 × 65),  
           = 2 for LFM (53 × 57),  
           = 3 for NMC octagonal (47 × 51),  
           = 4 for FNOC PE (63 × 63);  
 ILL,JLL . . . the lower left (I,J) coordinates measured on the  
                   source grid of the desired geographical region;  
 IMC,JMC . . . the number of (source) grid points to be taken in  
                   the I and J directions to cover the desired geographical  
                   region: the point (ILL,JLL) is counted as the first  
                   point;  
 ITYPE . . . . METLIB data type codes as in NMC office note 84:  
           = 8 for pressure in millibars,  
           = 16 for air temperature in degrees Centigrade or Kelvin,  
           etc. (as listed in section 4, page 12);  
 IFCST . . . . the forecast type:  
           = 0 for observed data,  
           = 12 for 12-hr forecast data, etc.;  
 OFACT . . . . the degree of interpolation for output fields:

- = 1 no interpolation
- = 2 interpolate to 1/2 mesh
- = 4 interpolate to 1/4 mesh;

MINDT . . . . the number of hours between map times.

The file generated by UNPACK is in standard format with a file header and a time series of data records.

Figure 4 is a sample listing of JUNPACK, the SUBMIT file for running UNPACK.

```

/JOB
JUNPACK.          METLIB
/READ, USERID
/NOSEQ
* UNPACKS DATA FROM BINARY SOURCE TAPES
* MAIN PROGRAM NEED NOT BE MODIFIED IF DATA GRID IS NOT LARGER THAN 65 X 65
* INPUT DATA (17 I3) ARE START YEAR/MONTH/DAY/HOUR, STOP YEAR/MONTH/DAY/HOUR.
* GRID, LOWER LEFT COORDINATES (I, J) OF SUBGRID, NUMBER OF (I, J)
* COORDINATES OF SUBGRID, DATA TYPE, FORECAST TYPE, DEGREE OF
* INTERPOLATION, AND NUMBER OF HOURS BETWEEN MAP TIMES.
GET, UNPACK/UN=METLIB.
FTN, I=UNPACK, R=0, L=0, PMD.
RETURN, UNPACK.
ATTACH, LIB/UN=LIB.
ATTACH, TAPE9=NAV7678/NA.
SKIPR, TAPE9, 1217.
DEFINE, TAPE10=SLP7678/NA.
ATTACH, TAPE10=SLP7678/M=W, NA.
LDSET, LIB=LIB.
L00.
/EOR
 76 11 01 00 77 03 30 18  4 20 29 10  7  8  0  2  6
/EOF

```

Figure 4. SUBMIT file JUNPACK for running UNPACK.

## 5.2 DECKS (Creates a Standard Format File from Digitized Fields)

DECKS performs for manually digitized fields the same function that UNPACK performs for the packed binary data sets. A uniform mesh compatible with the locations of the grid points of either the LFM or PE is laid over a hand-analysed polar stereographic National Weather Service sea level pressure chart or a hand analysis is performed on a chart produced by program PLOTGRD (section 5.8) or program DRAWMAP (section 5.9), and values are extracted. The grid can be either at the standard, half or quarter mesh spacing. An example of digitizing data from charts is given in the Appendix.

The first card read by DECKS gives IGRID, XIS, XJS, IMC, JMC, IFACT, ITYPE, N, and OFACT in a (I3,2F3.0,4I3,I5,I3) format. The first six words are the standard header from section 4. ITYPE is the data type explained in section 4, page 12. The number of fields to be read is N. IFACT is the resolution of the digitized input fields relative to the standard PE or LFM resolution; OFACT can be 1, 2, or 4, but must at least equal IFACT. If OFACT is greater than IFACT, the digitized fields will be interpolated to a finer (1/OFACT) mesh by biquadratic interpolation. This card is followed by the data sets, each beginning with a header card (6I2) specifying IYEAR, IMONTH, IDAY, I HOUR, IOBS, IFLAG; followed by the data to be read (in user-specified format) by the FORTRAN statements:

```
DO 10 J=1,JM
      READ (5,11) (ARRAY(I,J),I=1,IM)
10 CONTINUE
```

In DECKS the dimensions of ARRAY(IM,JM) are set by the user at the size of the input array and the dimensions of OUTPUT (IMM,JMM) and W(IMM,JMM) are set at the size of the array written on the output file in standard format. The

size of the output array depends on the input array and the degree of interpolation. Values in the DATA statement, following the DIMENSION statement, and the read format statement must also be made compatible with the input array.

DECKS expects the leading 9 or 10 to be left off of the digitized fields of pressure (in milibars). For example, the pressures 986.4 and 1021.8 would be read in as 86.4 and 21.8 (or 864 and 218). If the number read is less than 50.0 then 1000 is added, else, 900 is added.

A sample SUBMIT file for running DECKS is shown in Figure 5.

```
/JOB
JDECKS.          METLIB
/READ,USERID
/NOSEQ
* CREATES METLIB FIELDS FROM MANUALLY DIGITIZED FIELDS
* MAIN PROGRAM DIMENSIONS MUST BE MODIFIED FOR GRID SIZE
* NO DATA CARDS ARE NECESSARY IN JDECKS.  ON TAPE9 THE
* INPUT DATA IN (I3, 2F3.0, 4I3, I5, I3) ARE IGRID, XIS,XJS, IMC,JMC,
*   IFACT, ITYPE, N, DFACT
* ADDITIONAL INPUT DATA IN FORMAT (6I2) FOR EACH FIELD ARE IYEAR, IMONTH,
*   IDAY, IHOURL, IOBS, IFLAG
GET, DECKS.
FTN, I=DECKS, R=0, L=0, PMD.
RETURN, DECKS.
GET, WSUBLIB/UN=METLIB.
GET, TAPE9=RAWPRES/NA.
DEFINE, TAPE10=SLP/NA.
ATTACH, TAPE10=SLP/M=W, NA.
LDSET, LIB=WSUBLIB.
LGO.
/EOR
/EOF
```

Figure 5. SUBMIT file JDECKS for running DECKS. Note: No data cards.

### 5.3 WINDS (Calculations of Winds)

Program WINDS uses any of several models to compute surface wind fields. Input always consists of a time series of sea-level pressures defined at each point of a spatial grid. Models 6 and 8 also require the time sequences of surface air temperature and air-surface-temperature difference at the grid points. The Brown model (model 6) has the option of using dew-point depression fields as well. The air-surface temperature difference and the dew-point depression can be internally calculated from the surface and dew point temperatures, respectively. The information in the file header record on each data set (i.e., IGRID, XIS, XJS) completely defines the parameters necessary for geometric manipulations on the polar stereographic grid. User controlled output consists of fields of u and v components of winds and stresses and sensible and latent heat fluxes. All the output u and v components are relative to the grid reference frame and not the meteorological convention of east (u) and north (v).

The input and output units are as follows:

- TAPE 10 : input sea-level pressure,
- TAPE 11 : input surface roughness,
- TAPE 12 : input air temperature,
- TAPE 13 : input air-surface temperature difference or surface temperature,
- TAPE 14 : input relative humidity, dew point, or dew-point depression,
- TAPE 21 : output u component of the surface wind ( $\text{cm s}^{-1}$ ),
- TAPE 22 : output v component of the surface wind ( $\text{cm s}^{-1}$ ),
- TAPE 23 : output u component of the stress ( $\text{dyne cm}^{-2}$ ), or USTAR ( $\text{cm s}^{-1}$ ; models 6 and 8 only),

- TAPE 24 : output v component of the stress ( $\text{dyne cm}^{-2}$ ), or ALPHA (degrees; models 6 and 8 only),
- TAPE 25 : output sensible heat flux ( $\text{mw cm}^{-2}$ ), or u component of the thermal wind ( $\text{s}^{-1}$ ), and
- TAPE 26 : output latent heat flux ( $\text{mw cm}^{-2}$ ), or v component of the thermal wind ( $\text{s}^{-1}$ ).

Before using WINDS, the dimension of the interpolated grid should be set in the first DIMENSION statement after the comment cards.

There are three data cards in the SUBMIT file JWINDS (figure 6) which control processing in the program WINDS. The first two are in free field format meaning that the numbers must only be in the correct order and separated by commas or spaces. Extra spaces are ignored. The cards are as follows:

A. First card (free field format):

1. IYSTRT            year of the start time (e.g., 81),
2. IMSTRT           month of the start time,
3. IDSTRT           day of the start time,
4. IHSTRT           hour of the start time,
5. KSETS            number of data sets to analyze,
6. MODEL            model used to calculate surface winds:
  - = 1 geostrophic winds (section 6.8),
  - = 2 winds by the balance equation (section 6.10),
  - = 3 gradient winds (section 6.9),
  - = 4 constant turning and reduction (section 6.10),
  - = 5 not used,
  - = 6 Brown model (section 6.10),
  - = 7 not used,
  - = 8 Cardone model (section 6.10);

```

/JOB
JWINDS.          METLIB
/READ,USERID
/NOSEQ
* PRODUCES WIND FIELDS
* MAIN PROGRAM DIMENSIONS MUST BE MODIFIED FOR GRID SIZE
* INPUT CARD 1 IN FREE FIELD FORMAT CONTAINS START YEAR/MONTH/DAY/HOUR,
*   NUMBER OF SETS, MODEL, IORDWIND, CNST1, CNST2
* INPUT CARD 2 IN FREE FIELD FORMAT CONTAINS TWELVE CONTROL CONSTANTS
*   ROUGHNESS INPUT, AIR TEMP INPUT, AIR-SFC TEMP INPUT, HUMIDITY INPUT,
*   WIND OUTPUT, STRESS OUTPUT, HEAT FLUX OUTPUT, PRINTED OUTPUT, ROUGHNESS,
*   TEMP, TEMP DIFF, HUMIDITY
* INPUT CARD 3 CONTAINS A RUN TITLE OF UP TO 80 CHARACTERS
GET,WINDS.
FTN, I=WINDS, R=0, L=0, PMD.
RETURN,WINDS.
GET,WSUBLIB/UN=METLIB.
ATTACH,TAPE10=SLP/NA.
IFE,FILE(TAPE10,B01),NOFILE.
ATTACH,TAPE11=SFCROUF/NA.
IFE,FILE(TAPE11,B01),NOFILE.
ATTACH,TAPE12=SAT/NA.
IFE,FILE(TAPE12,B01),NOFILE.
ATTACH,TAPE13=SFCTEMP/NA.
IFE,FILE(TAPE13,B01),NOFILE.
ATTACH,TAPE14=DEWPNT/NA.
IFE,FILE(TAPE14,B01),NOFILE.
DEFINE,TAPE21=SFCU/NA.
ATTACH,TAPE21=SFCU/M=W,NA.
DEFINE,TAPE22=SFCV/NA.
ATTACH,TAPE22=SFCV/M=W,NA.
DEFINE,TAPE23=USTRESS/NA.
ATTACH,TAPE23=USTRESS/M=W,NA.
DEFINE,TAPE24=VSTRESS/NA.
ATTACH,TAPE24=VSTRESS/M=W,NA.
DEFINE,TAPE25=SENHEAT/NA.
ATTACH,TAPE25=SENHEAT/M=W,NA.
DEFINE,TAPE26=LATHEAT/NA.
ATTACH,TAPE26=LATHEAT/M=W,NA.
LDSET,LIB=WSUBLIB.
LGO.
ELSE,NOFILE.
COMMENT, INPUT TAPE NOT ATTACHED OR NOT REWOUND
ENDIF,NOFILE.
/EOR
  82  10  18  00  01  04  00  0.90  30.0
  0  0  0  0  1  0  0  1  0  0  0  0
    EMPIRICAL CONSTANTS,          18 OCT 82 00Z
/EOR
/EOF

```

Figure 6. SUBMIT file JWINDS for running WINDS.



- 7. IGRDWND           = 0 use the geostrophic wind in models 2, 4, 6, 8,  
                      = 1 use the gradient wind in models 4, 6, 8;
- 8. CNST1            for model 4, CNST1 is the fraction of the
- 9. CNST2            geostrophic or gradient wind used for the  
                      surface wind speed and CNST2 is the inflow  
                      turning angle in degrees to the left of the  
                      geostrophic or gradient wind direction. For  
                      models 6 and 8, CNST1 is the anemometer height  
                      used for the calculations (cm), if CNST1 = 0, the  
                      anemometer height is set to 10 meters (1000 cm).

B. Second card (free field format):

- 1. surface roughness input control (the roughness parameter used in  
model 4 and model 6 is 1000 times the drag coefficient; zero in  
model 6 indicates the surface is water and a drag coefficient is  
internally computed):
  - = 0 use the default value (second card, word 9, e.g. 1.5),
  - = 1 read the field once from TAPE11, then this one field of  
values will apply for all the remaining time steps of  
the program,
  - = 2 read the field each time from TAPE11;
- 2. air temperature input in either degrees centigrade or Kelvin:
  - = 0 use the default value (second card, word 10),
  - = 1 read the field once from TAPE12 (as with surface roughness),
  - = 2 read the field each time from TAPE12;
- 3. air-surface temperature difference input in either degrees  
Centigrade or Kelvin:
  - = 0 use the default value (second card, word 11),
  - = 1 read the field once from TAPE13 (as with surface roughness),
  - = 2 read the field each time from TAPE13;

alternatively the surface temperature may be used and the difference  
is found internally:

  - = 3 read the surface temperature once from TAPE13 (as with surface  
roughness),
  - = 4 read it each time from TAPE13;
- 4. humidity input (where the relative humidity should be fractional  
(0-1), the dew point depression should be in degrees Centigrade

or Kelvin, and the dew point should be in the same units as the air temperature):

- = 0 use the default relative humidity (second card, word 12, e.g. 0.70),
- = 1 read the field once from TAPE14 (as with surface roughness),
- = 2 read it each time from TAPE14,
- = 3 read the dew point depression field once from TAPE14 (as with surface roughness),
- = 4 read it each time,
- = 5 read the dew point field once from TAPE14 (as with surface roughness),
- = 6 read it each time,

5. surface wind output:

- = 0 no output,
- = 1 u component output on TAPE21 ( $\text{cm s}^{-1}$ )  
v component output on TAPE22 ( $\text{cm s}^{-1}$ );

6. stress output:

- = 0 no output (always for models 1 and 3),
- = 1 u component output on TAPE23 ( $\text{dyne cm}^{-2}$ )  
v component output on TAPE24 ( $\text{dyne cm}^{-2}$ ),
- = 2 USTAR output on TAPE23 ( $\text{cm s}^{-1}$ )  
ALPHA output on TAPE24 (degrees) (models 6 and 8, only);

7. sensible and latent heat flux or thermal wind output:

- = 0 no output,
- = 1 sensible heat flux output on TAPE25 ( $\text{mw cm}^{-2}$ )  
latent heat flux output on TAPE26 ( $\text{mw cm}^{-2}$ ) (model 6 only),
- = 2 u component of the thermal wind output on TAPE25 ( $\text{s}^{-1}$ )  
v component of the thermal wind output on TAPE26 ( $\text{s}^{-1}$ );

8. printed output:

- = 0 minimal,
- = 1 several lines per time step,
- = 2 several lines per grid point per time step.

The last four words on the second card are default values set by the user. If a default value is used, it is assigned uniformly over the whole field:

9. default roughness is the drag coefficient times  $10^3$  (in model 6, zero indicates an all water surface);
10. default air temperature ( $^{\circ}\text{C}$  or  $^{\circ}\text{K}$ );
11. default air-surface temperature difference ( $^{\circ}\text{C}$  or  $^{\circ}\text{K}$ );
12. default relative humidity (0-1).

C. Third card: This card is used as a run title, up to 80 characters long.

The following three cards, for example, would process 10 sets of data starting at 00Z 15 February 1982. Geostrophic winds would be produced with minimal printing:

```
82  2  15  0  10  1  0  0  0
0 0 0 0  1 0 0 0  0 0 0 0
```

#### GEOSTROPHIC WINDS

These next three cards select the empirical constants model with 70 percent reduction and 15 degrees of turning relative to the gradient wind. Stress fields are also produced using a drag coefficient of 0.0015:

```
82  2  15  0  10  4  1  .70  15
0 0 0 0  1 1 0 0  1.5 0 0 0
```

#### EMPIRICAL CONSTANTS

And finally the Brown model is used to compute winds at a height of 19.5 m from the geostrophic wind over water with input of air temperature, sea temperature, and dew point fields at each time step. Winds, stress and heat flux are output:

```
82  2  15  0  10  6  0  1950  0
0 2 4 6  1 1 1 0  0 0 0 0
```

#### BROWN MODEL

The value for ITYPE written on the output files is

ITYPE = 400 + MODEL for the surface roughness parameter,  
 480 + MODEL for the u velocity component ( $\text{cm s}^{-1}$ ),  
 490 + MODEL for the v velocity component ( $\text{cm s}^{-1}$ ),  
 500 + MODEL for the u stress component ( $\text{dyne cm}^{-2}$ ),  
 510 + MODEL for the v stress component ( $\text{dyne cm}^{-2}$ ),  
 530 + MODEL for latent heat flux ( $\text{mw cm}^{-2}$ ),  
 540 + MODEL for sensible heat flux ( $\text{mw cm}^{-2}$ ),  
 550 + MODEL for USTAR ( $\text{cm s}^{-1}$ ),  
 560 + MODEL for ALPHA (degrees),  
 570 + MODEL for u component of the thermal wind ( $\text{s}^{-1}$ ),  
 580 + MODEL for v component of the thermal wind ( $\text{s}^{-1}$ ),

so that ITYPE = 482 designates a surface u field generated by model 2.

The Brown model occasionally has problems with convergence, particularly in unstable stratification with a strong thermal wind. If this occurs a line is printed with the geostrophic wind, the air-surface temperature difference, the thermal wind, and an LTST code with four numbers. This code is deciphered as follows:

LTST(1) = 1    no convergence in  $u_x$  loop, test criteria increased  
                   from 1% to 10%;  
 LTST(2) = 1    no convergence in z/L loop, test criteria increased  
                   from 1% to 10%;  
 LTST(3) = 1    failed to converge with expanded test criteria,  
                   horizontal temperature gradient halved;  
                   = 2    still no convergence, quit trying;

LTST(4) = 1    no solution in subroutine PBL, horizontal temperature  
                  gradient halved;  
          = 2    still no solution, quit trying.

#### 5.4 PNTWIND (Time Series of Winds)

PNTWIND inputs the u (TAPE14) and v (TAPE15) wind components (in the grid reference frame) and creates time series of winds at up to five specific geographic locations by interpolation. First, the DIMENSION statement must be adjusted for grid size. The SUBMIT file JPNTWIND is shown in Figure 7. The first data card is formatted (5I3,I5,2I2) and specifies the starting time, the data interval in hours NINT, number of data sets in the time series KSETS, and the parameters NPT and IOU:

NPT . . . number of geographical points at which a time series is to be  
          created;

IOU. . . specifies the type of data to be output on TAPE9 (unformatted):

          IOU = 0 for u and v components of winds (grid reference  
                  frame),

          1 for speed and direction of winds (geographic  
                  reference frame),

          2 for u and v wind components (geographic reference  
                  frame) in "TAPE4" format.

Cards 2 through NPT+1 specify the north latitude and west longitude (degrees) of each point in (2F10.5) format. Modifications to PNTWIND can be used to access the u and v fields for almost any purpose.

```
/JOB
JPNTWND.          METLIB
/READ,USERID
/NOSEQ
* PRODUCES STATION TIME SERIES FROM METLIB FIELDS
* MAIN PROGRAM DIMENSIONS MUST BE MODIFIED FOR GRID SIZE AND SERIES LENGTH
*   AND NUMBER OF LOCATIONS
* INPUT DATA CARD 1 CONTAINS (5I3, I5, 2I2) START YEAR/MONTH/DAY/HOUR,
*   INTERVAL, SERIES LENGTH, NUMBER OF LOCATIONS, OUTPUT TYPE
* SECOND AND SUCCEEDING DATA CARDS HAVE LOCATION LAT AND LONG (2 F10.5)
GET, PNTWIND.
FTN, I=PNTWIND, R=0, L=0, PMD.
RETURN, PNTWIND.
GET, WSUBLIB/UN=METLIB.
ATTACH, TAPE14=SFCU/NA.
ATTACH, TAPE15=SFCV/NA.
ATTACH, TAPE16=SAT/NA.
ATTACH, TAPE17=SLP/NA.
DEFINE, TAPE9=PNTOUT/NA.
ATTACH, TAPE9=PNTOUT/NA, M=W.
LDSET, LIB=WSUBLIB.
LGO.
/EOR
  75 01 01 00 06 1460 2 2
  57.07000 163.33000
  63.50000 166.00000
/EOF
```

Figure 7. SUBMIT file JPNTWND for running PNTWIND.

"TAPE4" format was developed for time series analysis of current meter, pressure gauge, or wind data in a set of programs known as R2D2 (see Guide to R2D2 - Rapid Retrieval Data Display, by C. A. Pearson). "TAPE4" format consists of an unformatted nine word header field and four sets of unformatted data arrays. If available, the temperature and pressure fields are assigned to TAPE16 and TAPE17, respectively. The header field created is:

<u>Word</u>	<u>Description</u>	<u>Content</u>
1	grid type	"METLIB", IGRID, IFACT
2	model number	ITYPE
3	height	always "0"
4	start time	YYJJJHHMM
5	end time	YYJJJHHMM
6	series length	KSETS
7	data time interval, minutes	NINT*60
8	north latitude, decimal degrees	ALAT
9	west longitude, decimal degrees	ALON

Start time and end time are written as nine digit integers YYJJJHHMM where YY is year, JJJ Julian day, HH hour, and MM minutes. The data arrays are written to TAPE9 in order of east velocity, north velocity, temperature and pressure (the latter two arrays are zero-filled if data are unavailable). Data are written in arrays of maximum size 2000. If the actual series length is larger than 2000, the first 2000 values of all the parameters are written in the above order, then the next 2000, etc.

### 5.5 TRKWIND (Time Series of Winds Following a Track Line)

TRKWIND inputs up to four METLIB grid variables and creates time series of these variables along a user-specified time series of geographic positions. This program is thus helpful for generating wind, temperature, and/or pressure time series along the route of a steaming ship, drifting buoy, etc.

In order to run the program, the user must alter the DIMENSION statement to conform to the METLIB sub-grid in use. In the SUBMIT file JTRKWND (Figure 8) standard format METLIB data series are assigned to TAPE1 through TAPE4, as necessary, beginning with TAPE1, in any order, unless both wind components are to be output (IWIND = 1). In this case, the u component is assigned to TAPE1 and the v component to TAPE2. The position time series is assigned to TAPE10 (north latitude, west longitude, decimal degrees, 2F10.5). A free-field format data card must supply the following nine pieces of information:

- IYR . . . . starting year,
- IMO . . . . starting month,
- IDA . . . . starting day,
- IHR . . . . starting hour,
- NTIMES . . . the number of time steps to process,
- NVAR . . . . the number of METLIB variables to process,
- MPRINT . . . a diagnostic printing term (printing is disabled if MPRINT = 0, enabled if MPRINT = 1),
- IWIND . . . . a flag to indicate whether or not winds are being processed (no winds if IWIND = 0, if IWIND = 1 then the input u wind component is on TAPE1 and v component is on TAPE2),
- IOUT . . . . specifies the type of data to be output on TAPE20 (unformatted):
  - IOUT = 0 for either no wind data or for u and v wind components (grid reference frame),
  - = 1 for wind speed and direction (geographic reference frame),
  - = 2 for u and v wind components (geographic reference frame).

The output from TRKWIND consists of an unformatted binary record for each time step. Each record contains the time, latitude and longitude, and the interpolated METLIB variables.



```

/JOB
JTRKWND.          METLIB
/READ,USERID
/NOSEG
* INTERPOLATES METLIB FIELDS TO A TRACK LINE
* MAIN PROGRAM DIMENSIONS MUST BE MODIFIED FOR GRID SIZE
* INPUT IN FREE FIELD FORMAT START YEAR, MONTH, DAY, HOUR,
* NUMBER OF TIME STEPS, NUMBER OF VARIABLES, PRINT ENABLER,
* A FLAG FOR PROCESSING WIND DATA, AND A SPECIFICATION OF
* THE FORM OF WIND OUTPUT.
GET,TRKWIND.
FTN,I=TRKWIND,R=0,L=0,PMD.
RETURN,TRKWIND.
GET,WSUBLIB/UN=METLIB.
ATTACH,TAPE1=SFCU/NA.
IFE,FILE(TAPE1,MS),NOFILE.
ATTACH,TAPE2=SFCV/NA.
IFE,FILE(TAPE2,MS),NOFILE.
ATTACH,TAPE3=SLP/NA.
IFE,FILE(TAPE3,MS),NOFILE.
ATTACH,TAPE4=SAT/NA.
IFE,FILE(TAPE4,MS),NOFILE.
GET,TAPE10=SHIPTRK.
IFE,FILE(TAPE10,MS),NOFILE.
DEFINE,TAPE20=TRAKOUT/NA.
ATTACH,TAPE20=TRAKOUT/M=W,NA.
LDSET,LIB=WSUBLIB.
LGO.
ELSE,NOFILE.
COMMENT,INPUT DATA FILE NOT FOUND
ENDIF,NOFILE.
/EOR
 75, 1, 1, 0, 500, 4, 0, 1, 1
/EOF

```

Figure 8. SUBMIT file JTRKWND for running TRKWIND.

## 5.6 METLOOK (Prints Records from METLIB Files)

METLOOK reads and prints the header record and the first, last, and any chronologically-ordered, user-specified data records from an unformatted binary METLIB file. Up to four files may be processed. The data grid may be as large as  $63 \times 63$  without modifying this routine. The input files are assigned to logical units 11 through 14 (TAPE11, etc.; Figure 9), as required. User-requested record dumps require one data card for each record (free field format):

IUNIT . . . the number of the logical unit on which the data reside,  
 IYR . . . the year of the user-requested data record  
           to be dumped,  
 IMO . . . the month of the data record,  
 IDA . . . the day of the data record,  
 IHR . . . the hour of the data record.

```

/JOB
JMETLOK.          METLIB
/READ,USERID
/NOSEQ
* PRINTS METLIB FIELDS
* MAIN PROGRAM NEEDS NO MODIFICATION IF GRID IS NOT LARGER THAN 63 X 63
* HEADER RECORD AND FIRST, LAST, AND USER SPECIFIED DATA RECORDS ARE LISTED
*   FROM AS MANY AS FOUR SEPARATE METLIB FIELDS (TAPE11, 12, 13, 14)
* INPUT DATA IN FREE FIELD FORMAT ARE CHRONOLOGICALLY ORDERED USER SPECIFIED
*   DATA TIMES FOR IUNIT, YEAR, MONTH, DAY, HOUR. ONE CARD FOR EACH TIME.
GET,METLOOK/UN=METLIB.
FTN,I=METLOOK,R=0,L=0,PMD.
RETURN,METLOOK.
ATTACH,TAPE11=SFCU.
IFE,FILE(TAPE11,MS),NOFILE.
ATTACH,TAPE12=SFCV.
IFE,FILE(TAPE12,MS),NOFILE.
ATTACH,TAPE13=SLP.
IFE,FILE(TAPE13,MS),NOFILE.
ATTACH,TAPE14=SAT.
IFE,FILE(TAPE14,MS),NOFILE.
L90.
ELSE,NOFILE.
COMMENT,INPUT DATA FILE NOT FOUND
ENDIF,NOFILE.
/EOR
  11.66,10,1,0
  11.66,11,1,0
  11.67,10,1,0
/EOF

```

Figure 9. SUBMIT file JMETLOK for running METLOOK.

### 5.7 FORMAT (Creates formatted files from METLIB files)

It is sometimes necessary to transfer METLIB data files to different computing installations. Standard METLIB files are generated by unformatted

binary WRITE statements, and these files are not easily read by different computing systems. FORMAT is a utility program which converts standard METLIB files to formatted files which can be transferred to other installations.

In order to run FORMAT, it is not necessary to modify the program if the data grid to be converted is no larger than  $65 \times 65$ . By default, FORMAT will process one METLIB file assigned to TAPE1, writing the formatted output to TAPE2 with the header record in format (I3, 2F3.0, 4I3, I5, I3) and each data record as one line of time and data characteristics (6I2) followed by as many lines as necessary of (10E12.5) to output the grid variables. These formats were chosen to match the input header cards of the program DECKS.

In the SUBMIT file JFORMAT (figure 10) the user may override these default settings by providing as many as four data cards: the first specifying in free field format the number of files to process from the TAPE1 input unit (NFILS), and the final three cards specifying the number of format characters (NCHAR) and the formats for the header (IHDRFMT), time (ITIMFMT), and data (IDATFMT) records, respectively. The format for typing these three data cards is (I3, 77A1). If a substitution is made for a default parameter, all the data cards preceding the substitution must be entered with their default values. The data cards following the substitution do not need to be entered. For example, if the time and data characteristics are to be written in (3I3, 2I4, I2) instead of (6I2) the data file would contain the first two cards with their default values then the card with the substituted format specification:

```
1
14(I3,2F3.0,4I3,I5,I3)
12(3I3,2I4,I2).
```

```

/JOB
JFORMAT.          METLIB
/READ, PSHEAD
/NOSEQ
* WRITES FORMATTED METLIB FILES FROM UNFORMATTED BINARY INPUT
* PROGRAM NEEDS NO MODIFICATION IF DATA GRID IS NO LARGER THAN 65 X 65
* NO DATA CARDS ARE NECESSARY, HOWEVER,
* USER MAY OVERRIDE NUMBER OF FILES AND OUTPUT FORMAT DEFAULT BY SPECIFYING
* DATA CARD 1 (FREE FIELD FORMAT) NFILS, CARD 2 (I3,77A1) NCHAR, IHDRFMT,
* CARD 3 (I3,77A1) NCHAR, ITIMFMT , CARD 4 (I3,77A1) NCHAR, IDATFMT
GET, FORMAT.
FTN, I=FORMAT, R=0, L=0, PMD.
ATTACH, TAPE1=BPB3/UN=VLL, NA.
DEFINE, TAPE3=PBERB3/NA.
ATTACH, TAPE3=PBERB3/M=W, NA.
LGO.
REWIND, TAPE2.
COPYE1, TAPE2, TAPE3.
REWIND, TAPE3.
PACK, TAPE3.
/EOR
/EOF

```

Figure 10. SUBMIT file JFORMAT for running FORMAT.

## 5.8 PLOTGRD (Plots METLIB Fields)

PLOTGRD is the main program for performing graphical analysis on the data sets generated by the METLIB analysis routines. Both scalar and vector fields can be processed in a number of ways, and contour plots and vector fields can be drawn on a continental outline background using the NCAR Graphics utilities (McArthur, 1981).

The primary function of PLOTGRD is to allow the user to set up arrays with the proper dimensions for use in the plotting subroutines. All subroutines use variable-dimensioned arrays and need not be changed when data sets are changed. The secondary function of PLOTGRD is to set default values for a number of parameters which control the plotting. These values can be changed as desired by the user.

The program uses up to six arrays corresponding to a first and second scalar field (S1 and S2) and u and v components for two vector fields (U1, V1

and U2, V2). The logical unit numbers are assigned as TAPE11 through TAPE16:

TAPE 11 = S1,

TAPE 12 = S2,

TAPE 13 = U1,

TAPE 14 = V1,

TAPE 15 = U2,

TAPE 16 = V2.

These files only need to be attached if they are to be used. For example, for plotting vectors only, TAPE11 and TAPE12 may be omitted.

```
/JOB
JPLTGRD, T200.          METLIB
/READ, USERID
/NOSEQ
* PLOTS METLIB FIELDS
* MAIN PROGRAM DIMENSIONS MUST BE MODIFIED FOR GRID SIZE
* DATA CARD 1 IN FREE FIELD FORMAT CONTAINS IS1, IS2, IS12, IV1, IV2, IV12
* DATA CARD 2 IN FREE FIELD FORMAT CONTAINS START YEAR/MONTH/DAY/HOUR, KSETS,
*   IBACK, ITOPL
* DATA CARD 3 (I3, 7 A10, A7) CONTAINS TITLE LENGTH, AND TITLE
GET, PLOTGRD.
FTN, I=PLOTGRD, R=0, L=0.
GET, PSUBLIB/UN=METLIB.
ATTACH, TAPE11=S1/NA.
ATTACH, TAPE12=S2/NA.
ATTACH, TAPE13=U1/NA.
ATTACH, TAPE14=V1/NA.
ATTACH, TAPE15=U2/NA.
ATTACH, TAPE16=V2/NA.
GET, GRAFING/UN=GRAF.
BEGIN, NCAR, GRAFING, LS1=#LDSET, LIB=PSUBLIB, #, LOADMAP=LDMAP, MAPS=1.
BEGIN, NCAR, GRAFING, PLOTTER=NC11X11.
BEGIN, RPLOT, , TAPE2, P1=#BLK/. 4#.
/EOF
  1, 0, 0, 1, 0, 0
  82, 10, 18, 06, 01, 01, 01
022WIND VECTORS 18 OCT 82
/EOF
```

Figure 11. SUBMIT file JPLTGRD for running PLOTGRD.

The first data card in the SUBMIT file JPLTGRD (figure 11) specifies the type of variables to be plotted. The second card specifies the starting time

and the number of plots to be made. Cards 1 and 2 are read as free format input, so data card values need only be separated by a comma or blank. Card 3 is optional and is used to specify an additional title for the bottom of the plot.

Data Card 1:

<u>Variable</u>	<u>Value</u>	<u>Comment</u>
IS1	0	no scalar fields are to be processed (if IS1=0, set IS2=IS12=0 also),
	1	scalar field 1 (array S1) is to be contoured,
	2	scalar field 1 is to be read but is not to be contoured (i.e. is to be used only for differencing, see IS12);
IS2	0	no second scalar field is to be processed,
	1	scalar field 2 is to be contoured,
	2	scalar field 2 is to be read but not contoured;
IS12	0	the difference of the scalar fields S1-S2 is not to be contoured,
	1	the difference S1-S2 is to be contoured;
IV1	0	no vector fields are to be processed (if IV1=0, set IV2=IV12=0 also),
	1	wind vectors (arrows) only are to be drawn for vector field 1 (arrays U1 and V1),
	2	vector field 1 is to be read but not processed (i.e. is to be used only for differencing, see IV12),

3 isotachs (contours of the magnitude of the  
 vectors, ex. wind speed) only of vector field 1  
 are to be drawn,  
 4 both 1 and 3, i. e., both arrows and  
 isotachs of vector field 1 are to be drawn;  
 IV2 0 no vector field 2 is to be processed (if  
 IV2=0, set IV12=0 also),  
 1 wind vectors (arrows) only are to be drawn  
 for vector field 2 (arrays U2 and V2),  
 2 vector field 2 is to be read but not  
 processed (i.e. is to be used only for  
 differencing, see IV12),  
 3 isotachs only of vector field 2 are to be  
 drawn,  
 4 both 1 and 3, i. e., both arrows and  
 isotachs of vector field 2 are to be drawn;  
 IV12 0 no differencing of vector fields is to be done,  
 1 arrows only of vector field 1 minus vector  
 field 2 are to be drawn,  
 2 isotachs only of the magnitude of vector field 1  
 minus the magnitude of vector field 2 are to be  
 contoured,  
 3 both 1 and 2, i.e. arrows and isotachs of the  
 differences.

Data Card 2:

<u>Variable</u>	<u>Value</u>	<u>Comment</u>
IYSTRT	0	plotting is to begin with the first data set found on the input data files, otherwise IYSTRT gives the year of the beginning time for data processing, e.g. 71 for 1971;
IMSTRT	0	as for IYSTRT, plotting is to begin with the first data set, otherwise, IMSTRT gives the month of the beginning time, e.g. 6 for June;
IDSTRT	0	as for IYSTRT, otherwise, IDSTRT gives the starting day of the month, e.g. 15;
IHSTRT	0	as for IYSTRT, otherwise IHSTRT gives the hour of the beginning time, e.g. 12 for 1200Z;
KSETS	0	all data from the starting time until the end of the input data files are to be processed,
	N	if KSETS is greater than zero, then N sets of data will be processed, beginning with the data set at time IYSTRT, IMSTRT, IDSTRT, IHSTRT;
IBACK	0	no background of continental outlines is to be drawn,
	N	where N = 1,2, etc. a continental outline is to be drawn every Nth map;
ITOPL	0	no titles are labeled on map,
	1	map is labeled with data type and forecast time.



Note that setting IYSTR=IMSTR=IDSTR=IHSTR=KSETS=0 means that all data found on the input files will be processed.

Data Card 3: This card provides any desired title at the bottom of the plot, given the specification of 2 variables:

<u>Variable</u>	<u>Format</u>	<u>Comment</u>
NAUXTL	I3	the number of characters in the auxiliary title;
AUXTIT	7A10,A7	the character string which comprises the title (up to 77 characters are allowed).

If no auxiliary title is desired, either omit this data card entirely or give NAUXTL the value 0. An example of data card 3 is: 013EXAMPLE TITLE.

Figure 12 is a sample plot.

The next set of variables is assigned within PLOTGRD and can be changed by editing a copied version of the program:

JGRID . . . . the interval for drawing latitude and longitude lines,  
default is 10°;

IUSOUT. . . . determines whether or not U.S. state outlines are to be  
drawn if continental outlines are drawn, default of 1  
gives state outlines, set to 0 for no outlines;

IDOT. . . . 0 for continental outlines drawn by solid lines (default),  
1 for continental outlines drawn by dotted lines;

NHI . . . . 0 if highs and lows are labelled by H and L on all contour  
maps (pressure maps are always labelled H and L),  
-1 if highs and lows are not to be labelled (default).

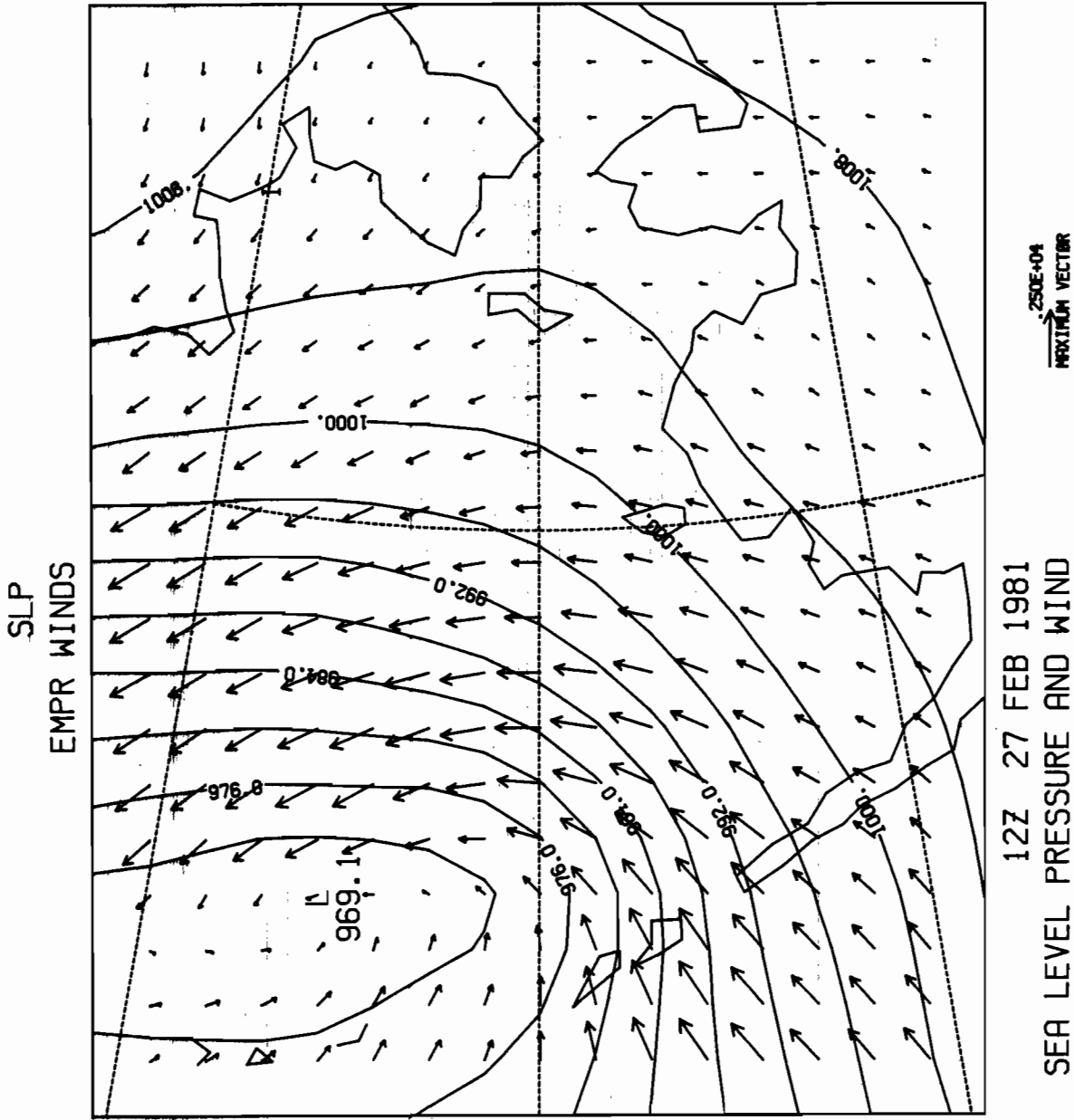


Figure 12. A plot (program PLOTGRD) of the sea level pressure field over the Bering Sea at 12 GMT 27 February 1981, and surface winds derived from model 4 (WINDS). Data are interpolated to  $\frac{1}{4}$  mesh (UNPACK or DECKS).

Contour intervals for various types of data are as follows:

PRESIN. . . . the contour interval for pressure fields, default is 4.0 mb;

TEMPIN. . . . the contour interval for temperature fields, the default  
is 1.0°C;

WINDIN. . . . the contour interval for isotachs of the wind fields,  
default is 400.0 cm sec<sup>-1</sup>;

OTHRIN . . . . the contour interval for any other data type, the  
default of 0.0 allows the NCAR routine to examine  
the data and choose an appropriate interval.

Contour intervals for plotting the differences between two data fields  
are as follows:

PDIFIN. . . . the contour interval for contouring the differences of  
two pressure fields, default is 2.0 mb;

TDIFIN. . . . the interval for contouring the difference of two  
temperature fields, default is 1.0°C;

WDIFIN. . . . the interval for contouring isotachs of the difference  
of two vector fields, default is 200.0 cm sec<sup>-1</sup>;

ODIFIN. . . . the interval for contouring differences of other types  
of data, the default is 0.0.

Any of these eight contour intervals can be set to zero, as are OTHRIN  
and ODIFIN. If this is done, the NCAR plot routines select an appropriate  
interval.

Parameters for the wind vector (arrow) plots are:

- VECMIN . . . . the smallest vector magnitude to be drawn, default is 0.0;
- VECMAX . . . . the largest vector magnitude to be drawn, the plot is scaled so that an arrow of this length will just reach from one data point to the next, default is 2500.0 cm sec<sup>-1</sup>;
- VDIFMN . . . . the smallest vector magnitude to be drawn when the difference of two vector fields is being plotted, any vector smaller than this will not be plotted, default is 1.0 cm sec<sup>-1</sup>;
- VDIFMX . . . . the largest vector magnitude to be drawn when the difference of two vector fields is being plotted, default is 500.0 cm sec<sup>-1</sup>.

If the wind is greater than VECMAX, only a point is plotted; if the wind is less than or equal to VECMIN no mark is plotted at the grid point.

## 5.9 DRAWMAP

This program creates plots of the polar stereographic background used with PLOTGRD. DRAWMAP is run by JDRWMAP (Figure 13) and generates working base maps for hand plotting and analyzing meteorological data for later digitization. The data card is described in section 4.

```

/JOB
JDRWMAP.          METLIB
/READ, USERID
/NOSEQ
* DRAWS A SPECIFIED GRID OR SUBGRID
* MAIN PROGRAM NEEDS NO MODIFICATION
* USER INPUTS IN FREE FIELD FORMAT IGRID, XIB, XJS, IMC, JMC, IFACT
GET, DRAWMAP/UN=METLIB.
FTN, I=DRAWMAP, R=0, L=0.
RETURN, DRAWMAP.
GET, GRAFING/UN=GRAF.
GET, WSUBLIB/UN=METLIB.
BEGIN, NCAR, GRAFING, MAPS=2, LB1=$LDSET, LIB=WSUBLIB. $.
BEGIN, RPLLOT, , TAPE2, P1=$BLK/. 3$.
/EOR
1, 1., 1., 65, 65, 1
/EOF

```

Figure 13. SUBMIT file JDRWMAP for running DRAWMAP.

## 6. SUBROUTINE DOCUMENTATION

### 6.1 Introduction

The bulk of the computations performed by METLIB-II are accomplished by its many subroutines. Since the source code of these subroutines is invariant, they are pre-compiled. The resulting relocatable code is stored in two subroutine libraries: WSUBLIB contains routines supporting computational programs such as UNPACK and WINDS, while the plotting programs access the PSUBLIB subroutine library. A list of subroutines contained in WSUBLIB with abbreviated documentation can be found in section 6.2. PSUBLIB makes extensive reference to the NCAR Scientific Computing Division Graphics package (McArthur, 1981). Consult the authors of METLIB-II for source listings and calling sequences.

## 6.2 List of Subroutines

BROWN	Called by model 6 (complete boundary layer solution)
CARDON	Called by model 8 (Monin-Obukhov solution)
DELTA	Finds planetary boundary layer (PBL) scale height delta for subroutine BROWN
DENSITY	Finds the air density over a grid
EDGE	Fills in the edges of two arrays
FILL	Fills an array with a constant
FIRST	Finds the first desired field on a file
FRAME	Sets up axes and labels for plotting
GEOWIND	Finds the geostrophic wind over a grid
GRADWND	Finds the gradient wind over a grid
GRIDCHG	Changes a scalar field from one METLIB grid to another
GRIDSET	Returns grid characteristics
HUMID	Calculates specific humidity
IJ2LL	Computes latitude and longitude from grid points
KONDO	Gives the neutral drag coefficient over water
LIU	Finds the roughness lengths for temperature and moisture
LL2IJ	Computes grid points from latitude and longitude
MODEL2	Calculates surface winds by vertically integrating the equations of motion (Augstein-Heinricy theory)
MODEL4	Calculates surface winds from empirical constants
MODEL6	Calculates winds at a specified height using the BROWN model (complete boundary layer solution)
MODEL8	Calculates winds at a specified height using the CARDON model (Monin-Obukhov solution)

NTERP	Interpolates a field to a point
PBL	Boundary layer model called by subroutine BROWN
PRNTOUT	Prints entire fields as calculated in program WINDS
PSU, PHU, PSI, PST, etc.	Surface layer parameter functions
ROUGH	Gives the roughness length
SD2UV	Computes u and v components from speed and direction
SMOGRD	Smooths or desmooths grid
THRMWND	Finds the thermal wind over a grid
UV2SD	Computes speed and direction from u and v components
ZETA	Finds the stability parameter

### 6.3 Interpolation (NTERP)

NTERP is a general subroutine for interpolating values to an arbitrary fractional I-J location from a regular grid-point array. To call NTERP, first determine whether the point is closer than one grid from a boundary, in which case the value is assigned via linear interpolation (i.e. KQUAD=5). For an interior point, biquadratic interpolation is used, which utilizes the values at the 16 surrounding points and is consistent with procedures in use at the National Meteorological Center (NMC).

### 6.4 Location on Subgrid (IJ2LL,LL2IJ)

IJ2LL calculates the latitude,  $\phi$ , and longitude,  $\lambda$ , from polar stereographic grid locations. The transformation equations are:

$$\lambda = 360^\circ - \tan^{-1} \left( \frac{XJ}{XI} \right) - 90^\circ + \text{ORIENT}$$

$$\phi = 90^\circ - 2 \tan^{-1} \frac{XMESH L \sqrt{(XI)^2 + (XJ)^2}}{a (1 + \sin 60^\circ)}$$

where XI and XJ are grid coordinates with the origin translated to the north pole and  $a = 6371.2$  km, the mean radius of the earth. XMESH L is the mesh length for the particular model. The orientation angle, ORIENT, is  $80^\circ$  for the PE and  $105^\circ$  for the LFM. This is the west longitude which is parallel to the j axis.

LL2IJ calculates the coordinates on the I-J grid given latitude and longitude by solving the transformation equations:

$$XI = \frac{11888.85 (\cos\phi)(\cos\alpha)}{XMESH L (1 + \sin\phi)}$$

$$XJ = \frac{11888.85 (\cos\phi) (\sin\alpha)}{XMESH L (1 + \sin\phi)},$$

where  $\alpha = 360^\circ - (\lambda + 90^\circ - \text{ORIENT})$ . The pole location is then subtracted to locate the point on the standard grids.

### 6.5 Speed and Direction (UV2SD,SD2UV)

UV2SD computes the speed and direction in the meteorological convention of the wind from grid-oriented vector components. The speed is simply  $\text{SQRT}(u^2 + v^2)$ . The wind direction is found from

$$D = \tan^{-1} \frac{XJ}{XI} - \tan^{-1} \frac{V}{U}$$

where XI and XJ are defined as in IJ2LL. SD2UV performs the reverse operation.



## 6.6 Thermal Wind (THRMWIND)

This subroutine calculates the non-dimensional thermal u and v wind component fields. These calculations are made only if one of models 6 or 8 is to be used or if it is specified in word 7 of the second input card to program WINDS. The vertical gradient of the geostrophic wind in the boundary layer is assumed to depend only on the surface horizontal temperature gradient computed by central differences and on the Coriolis parameter:

$$u_T \equiv - \frac{g}{f^2 \bar{T}} \frac{\partial \bar{T}}{\partial y} \qquad v_T \equiv \frac{g}{f^2 \bar{T}} \frac{\partial \bar{T}}{\partial x}$$

where g is the gravitational acceleration; f, the Coriolis parameter; and air temperature (SAT) is taken for the boundary layer average temperature,  $\bar{T}$ , at each grid point.

## 6.7 Grid Initialization (GRIDSET)

GRIDSET reads in IGRID, IFACT, and other parameters and adjusts them according to the degree of interpolation and the grid system used.

## 6.8 Geostrophic Wind (GEOWIND,EDGE)

In order to compute geostrophic wind, the components of the pressure gradient at each point of a grid field are found by central differences, dividing by twice the earth distance between adjacent grid points at that latitude. The grid spacing distance, the Coriolis parameter, and the air

density depend on the grid point. Subroutine EDGE assigns values to the boundary points from the closest interior points.

To generate geostrophic winds, the program WINDS (section 5.3) requires the pressure input on TAPE10 and the wind components ( $\text{cm s}^{-1}$ ) output on TAPE21 and TAPE22 in JWINDS. The first data card must have word 6 (MODEL) set to 1 and word 7 (IGRDWND) set to 0; in addition, word 5 on card 2 must be set to 1.

### 6.9 Gradient Wind (GRADWND)

A method of successive approximations is used for computing the gradient wind at each interior point (Endlich, 1961). In GRADWND the geostrophic wind speed and the radius of curvature are calculated at each point. The equation  $C = C_g - \frac{C_g^2}{fr}$  is iterated, where  $C$  is the gradient wind speed,  $C_g$  is the geostrophic wind speed,  $f$  is the Coriolis force, and  $r$  is the radius of the curvature (negative for a clockwise trajectory). EDGE is called at the end to assign gradient wind values to perimeter points.

For gradient wind output from WINDS, the submit file JWINDS must have the pressure input on TAPE10 and the wind components ( $\text{cm s}^{-1}$ ) output on TAPE21 and TAPE22; word 6 and word 7 on the first data card are set to 3 and 1 respectively; and word 5 on the second data card is set to 1.

### 6.10 Wind Models (MODEL2, 4, 6, 8, BROWN, CARDON, etc.)

There are four options available for modeling surface winds in the METLIB program WINDS. They are chosen by setting word 6 on the first data card in

JWINDS. It is imperative to note that all u and v components are relative to the reference grid and not meteorological convention.

Model 4 calculates a surface wind from the geostrophic or gradient wind by reducing the wind speed and rotating the wind direction by the amounts specified in CNST1 and CNST2 on the first data card in JWINDS. If CNST2 is positive, the rotation is to the left of the geostrophic (or gradient) wind. The surface stress may be calculated using a constant drag coefficient (set in word 9 of data card 2 in JWINDS). Surface wind components ( $\text{cm s}^{-1}$ ) are output to TAPE21 and TAPE22 by setting word 5 of card 2 to 1. When word 6 of card 2 is set to 1, the u and v components of surface stress ( $\text{dyne cm}^{-2}$ ) are written to TAPE23 and TAPE24.

Model 2 utilizes the vertically intergrated equations of motion, as suggested by Mahrt (1975) and by Augstein and Heinricy (1976), to yield a first-order approximation of surface winds from geostrophic winds. The equations are discussed in the original METLIB manual (Overland, et al., 1980). The output of surface wind and/or surface stress components is controlled by setting words 5, 6, and 9 on card 2 in JWINDS.

Models 6 and 8 are full single point atmospheric-boundary-layer models that compute the thermal wind from surface air temperature fields then use the thermal wind, the air-sea temperature difference, and the latitude to correct for stability and baroclinity of the boundary layer in deriving surface-wind speed and inflow angle from the geostrophic or gradient wind. MODEL6 uses the model of R. A. Brown (subroutine BROWN), summarized in Appendix A of the original METLIB manual (Overland et al., 1980). The model is also described by Brown and Liu (1982). MODEL8 uses the model provided by V. Cardone (subroutine CARDON), summarized in Appendix B of the original METLIB manual.

Models 6 and 8 utilize the geostrophic (or gradient) and thermal winds, relative humidity or dew point depression (model 6 only), and air-surface temperature difference calculated in WINDS to compute a variety of surface layer parameters at the height CNST1 (cm, word 8 of card 1 in JWINDS).

The second data card in JWINDS controls the output of models 6 and 8 including the u and v wind components ( $\text{cm s}^{-1}$ , word 5 = 1) on TAPE21 and TAPE22, either the u and v stress components ( $\text{dyne cm}^{-2}$ , word 6 = 1) or USTAR and ALPHA ( $\text{cm s}^{-1}$  and degrees, respectively, word 6 = 2) on TAPE23 and TAPE24, and (for model 6 only) the sensible and latent heat fluxes ( $\text{mw cm}^{-2}$ , word 7 = 1) on TAPE25 and TAPE26. In both models, USTAR is the friction velocity defined as  $\sqrt{\text{stress}/\text{air density}}$  and ALPHA is the turning angle between the geostrophic (or gradient) wind and USTAR. When ALPHA is positive the turning is to the left of the input wind signifying inflow toward a northern hemispheric low pressure center.

## 7. ACKNOWLEDGEMENTS

This report is a contribution to the Marine Services Project at Pacific Marine Environmental Laboratory. It has been funded in part by the Fisheries Oceanography Coordinated Investigations (FOCI). Subroutines IJ2LL, LL2IJ, and NTERP are adaptations of subroutines in use at the National Meteorological Center. Our thanks to J. E. Overland, S. Galt, V. L. Long, and C. H. Pease who have contributed to the development of METLIB-II. We are indebted to Ryan Whitney and Lai Lu for their help in preparing this manuscript.

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## APPENDIX: DIGITIZING DATA FROM CHARTS - AN EXAMPLE

We chose the Bering Sea as the region of interest for an example of creating a grid for digitizing data from National Weather Service charts. The first step is to locate the region on Figure 1 and decide which grid points provide the best coverage (Figure 14). The latitude and longitude of each corner of the grid may be determined by running a short program utilizing the subroutine IJ2LL (section 6.4) which converts (i,j) grid coordinates to latitude and longitude. Alternatively, the latitude and longitude of the corners may be determined graphically; an enlarged view of the gridded region of interest can be generated by DRAWMAP. The corners and equally spaced grid points are then drawn on a clear overlay. The grid size is determined by the size of the maps to be digitized.

The data will be read by DECKS where the Bering Sea grid is specified in the first header card by the grid coordinates (i,j) of the lower left corner and the number of grid points desired in the i and j directions. In this case the corner is (22,31) for a 6 by 5 grid.

The data at each grid point are recorded on a digitizing form starting at the lower left corner with respect to the master grid (Figure 14). Please note that DECKS expects the first line of data to correspond with the minimum j (i = minimum to maximum) so the digitized data are inverted with respect to the j coordinate of the master grid (Figure 14).

The gridded data are then typed into the computer in the following form:

- first DECKS header card,
- date/time header card,
- first data field,
- date/time header card,
- second data field,

and so on in the formats specified in section 5.2 (DECKS).



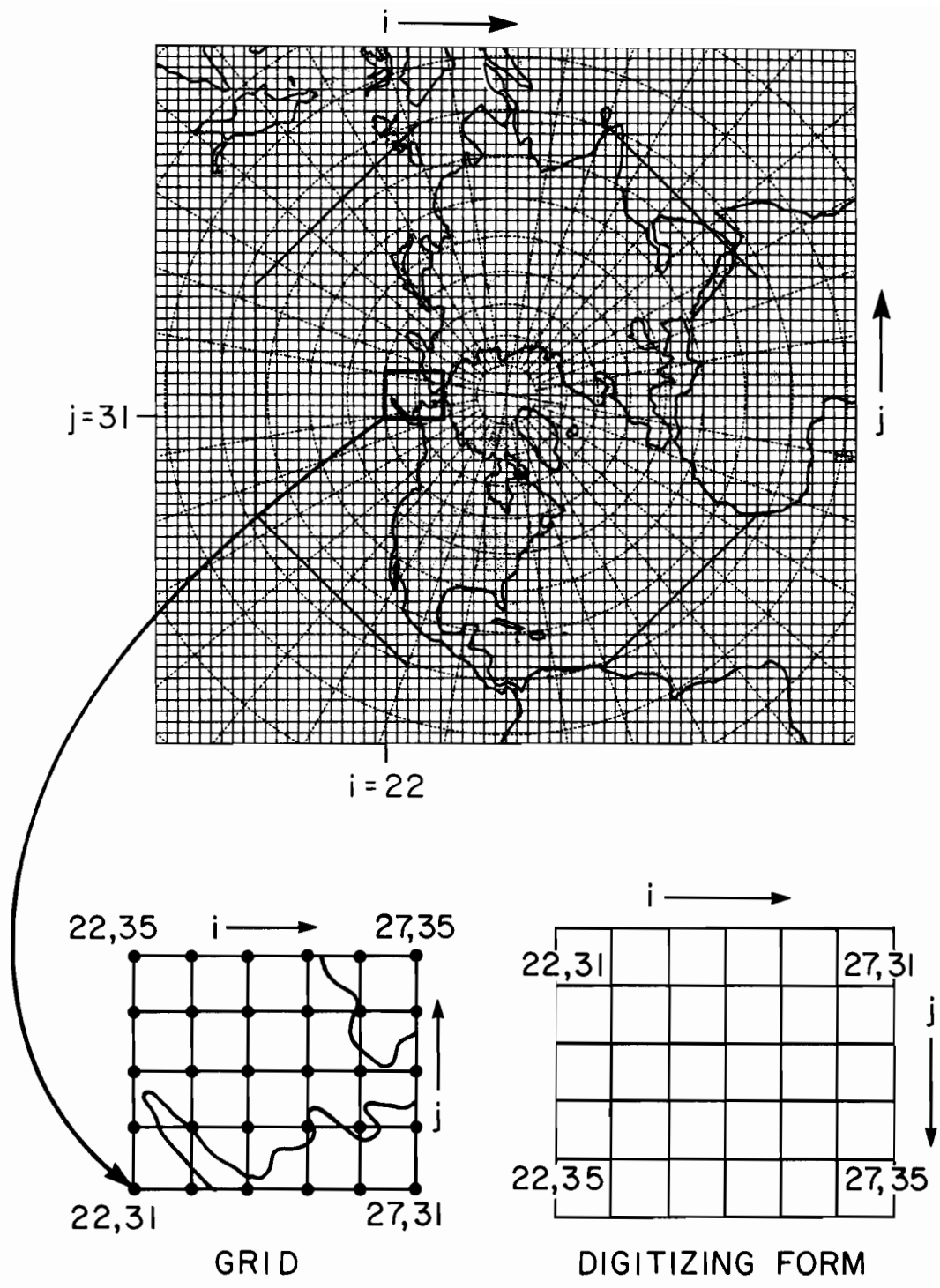


Figure 14. To digitize data from charts: locate the grid points that best cover the area of interest in Fig. 1, determine (lat, long) of the corner grid points, draw a copy of the grid on a clear overlay with size determined by the chart, record data at each grid point starting with lower left corner.